

Government Control with Cooperation of Riparian States and Cities

IN THE

Construction and Maintenance

OF

Levees, Bank Revetments and Channel Enlargements

FOR THE

Rivers of the Mississippi Valley

AS

Adequate Means of Flood Protection

RESULTING IN

Increased Wealth and Stability of Investment

ADDRESSES BY

CAPT. C. O. SHERRILL, CORPS OF ENGINEERS, UNITED STATES ARMY

WALSTON E. KNOBLOCH, ASSISTANT U. S. ENGINEER

GENERAL ARSENE PERRILLAT, CONSULTING ENGINEER

PROF. W. B. GREGORY, TULANE UNIVERSITY

A. M. SHAW, CONSULTING ENGINEER

SIDNEY F. LEWIS, CHIEF ENGINEER, ORLEANS LEVEE BOARD

FRANK M. KERR, CHIEF ENGINEER, BOARD OF LOUISIANA STATE ENGINEERS

GEORGE H. DAVIS, OF FORD, BACON & DAVIS, ENGINEERS

BEFORE THE

LOUISIANA ENGINEERING SOCIETY

NEW ORLEANS, JUNE 25, 1912

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**CALL FOR SPECIAL MEETING, LOUISIANA ENGINEERING
SOCIETY, SPECIFYING PURPOSE.**

New Orleans, June 18, 1912.

Prof. Douglas Anderson, President,
Louisiana Engineering Society,
In care of Tulane University,
New Orleans, La.

Dear Sir:

Losses of both life and property due to recent floods in the lower Mississippi Valley in repetition of past similar occurrences have awakened a most pronounced sentiment and demand on the part of American and European investors in the industries of this section that an effective plan be immediately executed which will absolutely and completely protect this section of the United States from flood conditions.

The Progressive Union, Contractors' and Builders' Exchange, New Orleans Real Estate Exchange, Algiers Improvement Association, Louisiana Homestead League, Orleans Parish Medical Society and the Louisiana State Medical Society have all discussed in a measure and offered their recommendations relating to river control. The Board of Trade and the Louisiana Engineering Society have as yet, as bodies, taken no action. There are two essentials to the accomplishment of any public work: First, capital; second, engineering construction. With the capital provided, the question is almost entirely one of engineering. Louisiana alone contains more than half of the levees now in service in the United States. The engineers of Louisiana have devoted a large part of their professional careers to the control of rivers, which should give them a prominent part in recommendations to the Legislative and Executive branches of the Federal Government, relating to the levee system of protection.

The object of this meeting is the presentation of different phases of the protection question by various members, in summarized form, and if conclusions can be reached, the issuance of positive recommendations on the part of the Society. As suggested before, after a careful investigation, the sentiment of the Eastern, Northern and Western sections of the country is in hearty accord with that of the South, and without question a bill offered to Congress recommending the continuance of the levee system and its control by the Federal Government will be favorably considered.

There has been extensive discussion of river regulation, but the real facts relating to this matter have not been sufficiently disseminated. Based upon the above considerations, we would request that a call be issued by you for a meeting of the Engineering Society at the rooms of the Society, Tuesday, June 25th, 1912, at 8 o'clock P. M.

Captain C. O. Sherrill, Corps of Engineers, United States Army, has consented to present an address to the Society at the meeting suggested. It is believed that other papers will be presented, the authors and titles of which are as follows:

1. "Reservoir Systems and their Relation to Flood Protection." Captain C. O. Sherrill, Corps of Engineers, United States Army.
2. "Possible Ultimate Height of Flood Waters Under the Levee System of Protection, with Suggestions as to Typical Sections of Levees." Walston E. Knobloch, Assistant U. S. Engineer.
3. "The Levee System as a Means of Control of the Flood Waters of the Mississippi River." General Arsene Perrilliat, Consulting Engineer.
4. "Forestation and its Relation to Flood Waters of the Lower Mississippi Valley." Prof. W. B. Gregory, Tulane University.
5. "The Effect of Mississippi River Floods on Land Reclamation and Drainage." A. M. Shaw, Consulting Engineer.
6. "Flood Protection of New Orleans." Sidney F. Lewis, Chief Engineer, Orleans Levee Board.
7. "Should the Federal Government Now Assist in the Control of the Levee System?" Frank M. Kerr, Chief Engineer, Board of Louisiana State Engineers.
8. "Increased Wealth to be Derived from Efficient Control of Flood Waters of the Mississippi River." George H. Davis, of Ford, Bacon & Davis, Engineers.

Hoping that the call of a special meeting for the purposes given will meet with your approval, we are,

Very truly yours,

GEORGE H. DAVIS,
WM. Von PHUL,
CHAS. J. HARDY,
A. T. DUSENBURY,
HORACE E. CRUMP,
SIDNEY F. LEWIS,
G. W. LAWES,
A. C. DUVAL,

WALTER P. VILLERE,
GERVAIS LOMBARD,
A. C. BELL,
ALFRED RAYMOND,
ARSENE PERRILLIAT,
W. H. WILLIAMS,
ALEXANDER ALLISON, JR.,
JNO. T. EASTWOOD.

In accordance with Section 3 of the By-Laws, at the request of the above named gentlemen, and by order of President Anderson, a special meeting of the Louisiana Engineering Society is called for Tuesday, June 25, 1912, at 8 P. M., in the Library of the Society. Inasmuch as this is a subject of live interest and importance to the profession in this community, and the speakers are well known engineers, who have given a great deal of thought and study to the matter, every effort should be made to attend this meeting.

Respectfully,

JAMES M. ROBERT,
Secretary.

RESERVOIR SYSTEMS AND THEIR RELATIONS TO FLOOD PROTECTION.

Captain C. O. Sherrill, Corps of Engineers, United States Army.

There are several related questions bearing on the best means of controlling and utilizing our streams, among which are the relations of forests, reservoirs, and soil erosion to stream flow; irrigation to navigable streams; and flood protection by levees, outlets or reservoirs. My subject this evening will be limited to the one phase showing the relation of reservoirs to floods. Others here will take up the several other methods of flood control.

The most vital question at the moment for the people of the lower Mississippi Valley is how best to secure protection from disastrous floods, such as the one now passing, and in the proper solution of this question the sympathy and assistance of the entire country should be ready to aid. Every flood brings forth a multitude of plans, each purporting to be the only one capable of providing the necessary cure, and most of them are brought out as something entirely new, yet each one will, on examination, be found to have been carefully considered and thoroughly investigated years ago. One of these propositions, renewed recently with great energy, has been to control these floods by means of reservoirs located near the headwaters of the tributaries.

In view of the fact that adequate reservoir systems for the control of floods in all streams would strike directly at the seat of the trouble, it seems remarkable that this method should not have been used long ago instead of the merely defensive method of elevation of overflowed land or the erection of levees.

The only perfect remedy for an evil is the removal of the initial cause, just as the sanitarian prevents yellow fever by destroying the germ-carrying mosquito; and in the same way to completely and finally prevent floods one naturally is led to the thought that their surplus waters must be held back in natural or artificial reservoirs; or even going a step further back toward the ultimate cause, why not by mechanical control of rainfall, give the desired uniformity of stream flow, and the desired moisture for growing crops at a time of their greatest need. This latter seems fanciful to all of us, yet only a few weeks ago the rain-makers were once more at work in Kansas attempting to break a two months drought, and who can say in view of the invention of the aeroplane, wireless telegraphy and other scientific advancement that this control of rainfall will not some day be possible.

If this ultimate cause of disastrous floods, of irregular and insufficient low water flow of streams—of blighted crops—cannot be removed, the next effort should be to secure such a partial remedy as may be afforded by impounding the excess waters as they fall in order to release them when they will be of the least harm and of most benefit to mankind. To those of us who would like to believe that the forces of nature operate according to fixed and beneficent laws, this most irregular and irrational distribution of rainfall does not speak well for nature's designs. In the Winter, when commerce is impeded by inclement weather and agricultural operations are impossible, come the heaviest rains only to flow away unused and a menace to every human interest along the Valley. The ideal of stream flows would be realized if it could be made perfectly uniform throughout the year or at least in proportion to the demands made upon it at different times of the year; and here again, as in rainfall, nature has very poorly done her work, and in so doing has left one of the greatest problems to the solution of river engineers—namely, to compensate for these irregularities of stream flow. In the summer and fall, when crops are to be nourished and moved to markets, the rainfall is least and streams are at their lowest and most inefficient stage; on the other hand, in the winter, when no use of them is possible, rain and snow are abundant and the streams are full to overflowing. Indeed, uniformity, the prime requisite for successful use of any agency of nature, is absolutely lacking. The question therefore is, can this stream flow be made uniform; if so, how and at what cost? To which I must answer that a reasonable degree of uniformity of flow can be secured by adequate systems of reservoirs properly located along streams where the topography is particularly adapted to such reservoirs, but as to the possibility of such control for the Mississippi below Cairo or of the practicability of the scheme, if possible, it is hoped that the following remarks will be of some assistance in determining.

Reservoirs are of two kinds, natural and artificial. Of the former, the most notable examples are the great lakes, which together form a storage basin sufficient to control and give uniformity of flow to the Niagara River with a mean annual discharge of 232,800 cubic feet per second, or about 75 per cent. of that of the Ohio, and practically equal to that of the upper Mississippi and Missouri combined. The ratio of the minimum to the maximum mean discharge of the Niagara is 1 to 1.19; of the Missouri 1 to 29; of the Ohio 1 to 28; and the upper Mississippi 1 to 10.3. Without further demonstration, the above is proof positive that under suitable conditions a stream, no matter how large, can be controlled, and the above ratios show further that on the upper Mississippi, where nature has provided more than 1,000 storage lakes, the variation is only 1 to 10 against 1 to 28 on the Ohio. Now let us examine this great lake storage basin for some indication of the areas of reservoirs required to give this

uniformity of flow at its outlet. The total drainage basin of the St. Lawrence above Niagara Falls is 265,950 square miles, of which all the rainfall is controlled by Lakes Superior, Michigan, Ontario and Erie, whose water surface alone is 87,400 square miles, or more than one-third of the entire drainage basin. So, from this analogy we might safely say that if we could control the entire rainfall of any basin and utilize one-third of the area for the actual water surface, the problem would be perfectly solved. Obviously such a proposition is an impossibility; therefore, a further examination is required to learn how much is the best artificial reservoir area that will give the needed protection. This calculation was first made, in 1858, by Humphreys & Abbott in their exhaustive survey of the Mississippi River, and later by Captain Chittenden, in 1897, in his examination of the headwaters of the Missouri for reservoir sites, and very recently by the Pittsburg Flood Commission for controlling the Alleghany and Monongahela Rivers in order to protect Pittsburg from flood damage. Humphreys & Abbott found that it would have required the control of the rainfall over 90,000 square miles, an area much larger than the whole mountain region drained by the Ohio, in order to hold back the Ohio River floods above the danger stage at Cairo. This report says "the impracticability of the scheme requires no further demonstration since this flood (of 1858) was of the character which the reservoir system was best adapted to control, it was of the upper tributaries of the Mississippi, all of those below the Ohio being at low stage."

The next investigation, that of Captain Chittenden, has often been quoted as favoring reservoirs; he did favor them and very properly at the headwaters of the Missouri for irrigation, and his report was the basis of the present irrigation service, but he did not consider the scheme practicable for flood control on the lower Mississippi. The Pittsburg Flood Commission found that by the construction of seventeen dams at a cost of \$21,672,100.00, so located on these streams as to hold back the water of 53.8 per cent. of the entire drainage basin above Pittsburg, the greatest flood ever known there would have had its crest reduced from 35.5 to 27 feet, a total reduction of 8 feet at Pittsburg, but that in certain floods several of these reservoirs filled up before the end of the flood. It was also found that with the assistance of a levee along the entire city front from 9 to 30 feet high, averaging 14 feet, the city would be protected from overflow; or that a levee 10 to 47 feet high, averaging 30 feet, would, without any reservoirs, prevent all of the flood damage at a considerably lower cost. The Commission further found that the fifteen next practicable dams would give a flood reduction at Pittsburg of only eight-tenths of a foot at an additional cost of \$6,000,000.00, or 17½ per cent. of the total cost of the projected forty-three dams, and these fifteen were accordingly thrown out of consideration as being impracticable. No study of the effect of floods on the Mississippi

River was made by this Commission, nor on the Ohio, except as incidental to this study of local flood conditions at Pittsburg. Assuming that the data secured by this Commission is correct, the question that naturally suggests itself is: If it is necessary to hold back all of the waters falling on 53.8 per cent. of the total drainage basin, assisted by a fourteen-foot levee in order to protect a single city, ideally located for such protection by the reservoir system, at the foot of the mountainous area most available for reservoirs, how large an area must be controlled to prevent dangerous floods at and below Cairo with a drainage area above it on the three tributary streams of 908,130 square miles? It would be madness to assume a possibility of controlling the entire rainfall of more than 50 per cent. of this vast area, but even suppose one-fifth of it, or 180,000 square miles, would be sufficient, then the reservoirs must control the rainfall of an area far larger than the entire mountain region drained by the Ohio and Missouri.

The above considerations alone would condemn the reservoir scheme of flood control without going into the important elements of cost; the physical possibility of securing enough reservoir sites at proper locations; the practical operation of these reservoirs so as to give the desired results; or the damage that would constantly threaten the lower valleys from breaking of these dams.

However, let us see how much a system of reservoirs to control the Ohio would cost. Mr. O. H. Leighton, who precipitated the recent revival of the reservoir-river-control theory in a paper written for the Inland Waterways Commission in 1908, claimed that at a cost of \$125,000,000.00 the Ohio floods could be controlled and the low water flow much benefited. He based his statement on a superficial examination of a few sites on the Monongahela and Alleghany, trusting to small scale maps for information on all other streams. As an indication of the inaccuracy of his determinations I will say that he found a storage capacity of 173,000,000,000 cubic feet in eighteen reservoirs on the Alleghany and Monongahela Rivers, whereas the Pittsburg Flood Commission was able to find only a capacity of 80,000,000,000 cubic feet in forty-three reservoirs, or less than one-half as much as the Leighton estimate in more than twice as many reservoirs. A subsequent and more thorough investigation has led to the conclusion that the cost estimated by Mr. Leighton should be increased to five or ten times his figures. Recently, in a letter to Senator Ransdell, Mr. Leighton has receded from many of his former positions and admits that the levee system is preferable for immediate protection.

Ignoring for the moment this practical question of cost, and assuming that, with enough reservoirs, the floods at Cairo could be controlled, where would it be necessary to make the locations so as to secure the benefits desired? Obviously they could not all be placed in the mountainous headwaters where land is cheap and storage

basins relatively easy to secure, because frequently (and I might truthfully say generally) destructive floods occur on the lower Ohio when there are no serious flood conditions at Pittsburg or any other headwater locality. For example, the highest water ever known at Pittsburg was on March 15, 1907, when the gauge there was 35.5 feet, but we look in vain for any corresponding high stage at Cairo during the next three months. On the contrary, we find that the highest stage (50.3 feet) at Cairo that year occurred two months earlier, namely, on January 27th, while the only flood stage at Pittsburg previous to that date was on January 20th, when the river was at the comparatively low stage of 23.3 feet, or 11.7 feet lower than on March 25th; and you will observe that even this stage at Pittsburg had no connection with the highest water at Cairo since only seven days intervened for the crest to travel 964 miles.

Numerous other similar cases could be cited to show that many of the destructive floods occur at points on the lower river before the upper rivers are in flood. During this year's disastrous high water there were no serious floods at Pittsburg, nor even at Cincinnati, and the reason is that at least eight violent and general storms swept up the Mississippi and Ohio Valleys from the Gulf, each one causing additional flood heights throughout the lower basins in advance of the corresponding heights further up on the small tributaries. In this connection the much greater rainfall on a given area along the lower river, as compared with that in the mountains, is not usually given the weight it deserves.

The above facts being true, does it not show conclusively that reservoirs, to be effective in preventing floods at any particular locality on the river necessarily must be constructed in the immediate vicinity of those localities.

Now, where will we find sufficient reservoir sites for our purposes on the twenty-three main tributaries of the Ohio below Pittsburg having a total drainage area of 190,000 square miles as against that of the basin above Pittsburg with only 18,900 square miles. These tributaries flow through the most thickly settled and prosperous sections of the country, where land values are high, and where a large part of the land is too flat for reservoirs, even if other conditions allow their construction. The residents of these thickly settled localities would oppose such constructions on account of the damage to railways and other properties, as well as the menace to health caused by the wide fluctuations of the water surface of the reservoirs, as they would be successively filled and emptied each year.

The presence of dams of the heights proposed, in some cases as much as two hundred and fifty feet, would be a source of constant danger due to the possible breaking, such as occurred at Johnstown, Pa., where over 4,000 people were killed. It may be said that such dangers can be prevented and so they can, but the fact remains

that they do occur even in the best types of earth or concrete construction, as happened only last fall in Austin, Pa. Supposing a dam holding 844,000,000 cubic feet of water with four others below it on the same stream holding all told nearly 4,000,000,000 cubic feet should break, can you conceive of the disaster that would result, not only immediately below, but for many hundred of miles down the valley, due to this vast mass which would probably break each dam in succession on its path of destruction. The above is the condition proposed by the Pittsburg Flood Commission for five dams, one above the other on one of the branches of the Monongahela. This mass of water would make a volume twenty feet deep by a thousand feet wide by thirty-five miles long, and yet writers favoring reservoirs for flood control laugh at the idea of danger from these breaks. No longer ago than October 6, 1911, such a break occurred in the case of two earth and concrete dams on the Black River, Wisconsin. The upper one broke from over-topping, and the mass thus released destroyed a larger one six miles below it. About the same time came the Austin, Pa. disaster, due to the failure of a reinforced concrete dam.

Taking the above brief summary of the facts into consideration, I must conclude that the control of the Mississippi Floods by reservoirs is impracticable of accomplishment, and that the next best thing must be relied upon, namely, the levee system with bank protection which should be completed as rapidly as possible.

**POSSIBLE ULTIMATE HEIGHT OF FLOOD WATERS UNDER
THE LEVEE SYSTEM OF PROTECTION, WITH SUG-
GESTIONS AS TO TYPICAL SECTIONS OF LEVEES.**

Walston E. Knobloch, Assistant U. S. Engineer.

After each great flood, especially when disastrous effects have been caused by crevasses, we find persons expressing doubt as to the efficiency of levees alone as a means of protection and offering remedies other than levees for the prevention of floods. To these persons it should be made known that the high water of 1912 has not exceeded, except in a few stretches of the river, the expected and long before-hand predicted heights.

It is a very difficult matter to predict the ultimate high water of the future for the following reasons: First, the culminations of floods are at different periods in different tributaries of the Mississippi, and, second, a given gauge height at any station will not always produce the same gauge height at a lower station unless the area of cross-section remains constant between the two stations and there is no change in the resistance of flow or in the flow that gives velocity. Considering these difficulties, it is in my opinion remarkable that the predicted heights of the Mississippi River Commission have been verified so closely.

The following table gives the Mississippi River Commission ultimate high water and the high water of 1912 at the important gauge stations on the Mississippi River:

STATION	Mississippi River Commission High Water	High Water 1912	Elevation of Zero of Gauge Cairo Datum
Cairo	53.2	54.00	290.84
Memphis	43.6	45.30	203.97
Helena	54.1	54.40	161.98
Arkansas City	56.30	55.30	116.44
Greenville	50.50	50.50	108.00
Vicksburg	55.05	51.50	66.04
Natchez	54.00	51.40	36.89
Red River Landing	52.50	53.20	23.85
Bayou Sara	45.70	47.20	23.95
Baton Rouge	43.20	43.80	20.06
Donaldsonville	34.95	34.80	19.48
College Point	29.80	30.18	21.24
Carrollton	21.00	20.70	20.91
Fort Jackson	9.00	8.50	19.26

The water would have been higher from Memphis to Natchez had it not been for the many crevasses which occurred before the crest of the flood had passed between these points. The water would probably have been somewhat higher at Memphis, Helena and Arkansas City, much higher at Greenville and Vicksburg, and about one and a half to two and a half feet higher at Natchez, but it would have been lower at Red River Landing, Bayou Sara and Baton Rouge. This last statement may appear strange, but the lowering of the water between Arkansas City and Vicksburg diminished the velocity of the current at points below for the reason that the head was lessened and the force that produces velocity was lessened. The slope in the lower river became flat and remained so until the water from crevasses returned over the land and through Old River to the Mississippi River just above Red River Landing.

To what extent this reduction in slope prevailed, may be judged by considering this fact: The date of Panther Forest and Salem crevasses was April 12th. From this date until April 28th, the water fell 4.1 feet at Vicksburg and rose three feet at Baton Rouge. This fall at Vicksburg, which continued sixteen days, was not felt at Baton Rouge, except only in the way of producing a stand in the water for six days. The water at Baton Rouge, if the effect of crevasses is not felt, begins to fall from six to twelve days after the fall begins at Vicksburg.

For ten miles above Old River the Mississippi River is unleveed and the water from Panther Forest and Salem crevasses returned to the Mississippi River not only through Old River but over this unleveed land. This sudden addition of a great volume of water just above Red River Landing caused abnormal gauge heights at Red River Landing, Bayou Sara and Baton Rouge, and more so at Bayou Sara for the reason that from Red River Landing extending down to within a short distance of Bayau Sara the water during flood spreads over a large area but is contracted between levees—or levees and hills—at Bayou Sara and below.

Those who have studied the gauge relations for stations on the Mississippi River have observed that any cross current running into the river, and especially at a point where the influx is not habitual, will cause the velocity of the water to be checked. The effect is the same as if some obstruction had been placed in the stream and the water will rise far above the height it might have attained had the same increment come down through the river above. This is often the case at Old River just above Red River Landing and where the flow is sometimes away from and sometimes toward the Mississippi River.

Since 1897, I have observed and studied the effects of return water through Old River and have plotted gauge relation curves for each high water. In every case when the direction of flow has been to

the Mississippi River there have been abnormal gauge heights from Red River Landing down the river for a distance, depending on the amount of influx.

The Mississippi River Commission have established a provisional grade which is expected to be two feet above the ultimate high water. In the foregoing table the ultimate high water was obtained by deducting two feet from the Mississippi River Commission Grade. This grade is tentative and the Mississippi River Commission I believe, know that changes are necessary and have considered increasing the grade in some localities.

In their annual report for 1911, the Mississippi River Commission estimate that little less than 54,000,000 cubic yards will be required to complete the levee system to grade and standard section. Of the 1,565 miles of levee in the system, there were built up to 1911 inclusive, 1,496 miles, of which length 636 miles are in the Fourth District. Captain Sherrill has charge of the Fourth District and I, as his assistant on levee work, am familiar with these 636 miles of levee, I feel sure that had there been no crevasses between Arkansas City and Vicksburg, there would have been none in the Fourth District. The crevasses that occurred in the Fourth District were Torras, Hymelia and Cannon. Cannon was closed. Of course, other crevasses occurred on the Mississippi River South of Warrenton, but they were in private levees not constructed in whole or in part by the United States or by the State and not considered as a part of the system. Without a crevasse between Arkansas City and Vicksburg, the water from Red River Landing down would not only have been lower, but the high water period would have been of shorter duration.

The recent flood was due to an unusual combination of high waters from the Ohio, Cumberland, Tennessee, Upper Mississippi, St. Francis, Arkansas and White Rivers, with unusual rains during the flood in the Lower Mississippi River. There is no reason to believe that any future flood will exceed very much, if at all, this last one. Therefore, I believe that the ultimate high water of the future will not vary much from the heights that would have been attained at different stations had there been no crevasses. We should expect higher water from Memphis down to Natchez, lower water from Red River Landing to Donaldsonville, and practically the same stages from College Point to the Head of the Passes.

Now recently, a number of persons have asked me about the high water and have made many very absurd recommendations for flood prevention and have insisted that the building of levees raises the bed of the river. I cannot understand by what process of reasoning they assert that levee construction will raise the bed of the river when the natural conclusion should be that increase channel discharge would mean energy tending to deepen and enlarge the channel. In contradiction to this impression or belief that levee construction

will raise the bed, I submit the fact that repeated soundings taken over the same sections of the river have proved that this is not true.

Levee Sections.

The Board of District Officers recommended in 1899 that the Standard Levee cross-section should have an eight foot crown with front and rear slopes of one on three for levees not exceeding twelve feet in height. For higher levees a banquette is added on the land side, beginning eight feet below the crown with top slope of one on ten, rear slope of one on four and width of twenty feet. Where a levee is built of good material this section is all that is required, except in cases where levees are built on very loose or porous soil, or where the base is over the bed of some bayou or stream which has silted up and where the underground material is a light blue sand which easily becomes semi-liquid. In such cases the embankment should be built of a different section by increasing the base and building the lower part of the embankment with slopes of one on six. In this way the hydraulic head is diminished by friction. This extension of the base prevents free seepage under the base, arrests sand-boils and diminishes the subsidence in the base of the levee. How high this one on six slope should be built depends altogether on the condition of the material under the base of the levee.

At Bougere, in the Lower Tensas Levee District where there was, in places, a subsidence in the base, the levee across Boggy Bayou was built 29.8 feet high, the lower 11.3 feet in height, was built with slopes of one on six, and the upper 18.5 feet in height was built with slopes of one on three. There was no subsidence in the base across this bayou, although on each side for a distance of several hundred feet there was subsidence of from 1.0 to 2.2 feet.

Unfortunately, levees must be built of the material found in the neighborhood. The soils along the Mississippi River are loam, sand, and a clay known as "buckshot." All of these soils are sometimes found in one neighborhood in different layers and sometimes they are found mixed. The best soil for levee construction is "buckshot" with a small percentage of sand or loam mixed with it. Levees built with this soil do not become easily saturated, do not easily wash, nor slough on the land slope; but they are the ones in which the cray-fish do most of their damaging work. Levees built of loam or sand are more easily saturated and are more apt to slough on the land slope; they are also easily wave-washed; but the cray-fish do not work very much in either of these soils. Levees built entirely of these materials should have the following increased section: where they are less than twelve feet in height the land slope should be one on four and on higher levees the banquettes should be wider with rear slope of one on five.

That part of the levee system that is below New Orleans, even if built to ample height and section is subjected to still another destructive agency which may at times become serious enough to threaten that section of the country with overflow. I refer to the damage done by waves during storms at medium as well as high stages of the river and by fast ocean going steamers. There is no question but that this trouble will be aggravated with the advent of larger ships using our thirty-five foot channel through South-West Pass. Recognizing this, the United States Engineers have adopted a method of protection against wave-wash more permanent than the usual wooden revetment and also more efficient. It consists of placing a concrete facing on the river slope of the levee and extending it vertically three feet into the berme of the levee. Some of this revetment has been in use five years and in addition to serving as a protection against wave-wash, has effectively cut off the seepage even on levees of reduced section built by wheelbarrows. The annual cost of clearing and mowing a levee thus protected is cut in half. But probably not the least commendable feature of this revetment is the insurance it offers against perforation by rats and cray-fish. The importance of this can be realized when it is remembered that the Live Oak crevasse was caused by a cray-fish hole in a levee of standard height and section and protected with a cypress revetment not more than two years old. To Mr. John Klorer, U. S. Junior Engineer, and a member of your Society, is due the credit of devising this method of protection.

During the year ending May 1, 1912, contracts were entered into by the United States for the construction of about 710,000 cubic yards of levee work at an average cost of 14.33 cents per cubic yard. Even at an advanced price of twenty-five cents per cubic yard the levee system on the Mississippi River could be completed to the Mississippi River Commission grade and to standard section for less than \$15,000,000. If built to a grade two feet higher than the present Mississippi River Commission grade, and to the standard section the cost would be less than \$38,000,000. If this size levee would not satisfy all, they could have concrete facing and curbing placed on the river slope for \$40,000,000. This certainly would make our levees safe and strong enough to hold any flood expected in the Mississippi River and very little attention would be required during high water. Can reservoirs or outlets which would reduce the flood heights for any length of the river be built for an amount so small?

THE LEVEE SYSTEM AS A MEANS OF CONTROL OF FLOOD WATERS.

General Arsene Perrilliat, C. E.

I had expected to carefully prepare a paper to read before you this evening, as the gentlemen who have preceded me have done. The papers read by them are full of information and concise data, and have great engineering value. Time, however, has failed me to prepare this paper. I am, therefore, going to trespass upon your time for a few minutes and endeavor to describe to you the evolution of my belief in the levee system, which has come from some twenty years of observation and some study of the Mississippi River. I will deal in generalities perhaps more than in exact figures, and I may also have to beg you to forgive me if I repeat a few of the remarks I had the pleasure of addressing to the Society a short time ago upon a similar subject.

The flood control of the Mississippi River is such a tremendous problem that figures give only a very vague and inadequate conception of what is involved. For instance, if we say that the flood discharge at Vicksburg is 1,700,000 cubic feet per second, it sounds ordinary and is said quickly, but that is something enormous—1,700,000 cubic feet per second. If we try to reduce this to cubic yards of water per 24 hours it amounts to 5,600,000,000 cubic yards per 24 hours, 1.2 cubic miles of water for 24 hours; in a month it would be 36 cubic miles of water. As a matter of fact, the actual discharge during one year is, on an average, 159 cubic miles of water, a quantity so large that we cannot quite conceive what it means. It is enormous. I would like to also say, incidentally, that at flood stages these 5,600,000,000 cubic yards of water per 24 hours carry in suspension some 7,000,000 cubic yards of earth or sediment. In other words, there passes Vicksburg in 24 hours as many cubic yards of earth on its way to the Gulf as we put on the levees in about $1\frac{1}{2}$ or 2 years of construction.

The Mississippi drainage basin (this has been repeated so often it is nearly trite to say it) drains nearly 41 per cent. of the United States. It has an area of 1,250,000 square miles. It is some 1,800 miles, if I remember right, wide in longitude, some 1,500 miles long in latitude, draining some 10 entire States, parts of 22 others and parts of 2 provinces of Canada. The area drained, the water from which passes Vicksburg, is equivalent to the combined area of Austria, Germany, France, Holland, Italy, Spain, Norway, Portugal and Great Britain. We are dealing, therefore, with a pretty large

proposition, something where human agencies, I fear, are so insignificant that all which engineering skill can hope to do is to train, help and try to guide nature to do the work which is required for the protection of property and for the enjoyment of life by those who reside in the Valley. It might have been a wise thing for the settlement of the Valley to have been delayed some 2,000 or 3,000 years until it had been filled up and raised so that the annual floods might not inundate and overflow the land. American enterprise, however, decreed otherwise, settled on the banks of the river, found there rich lands, built their few protection levees around isolated localities, and acquired wealth. The population of the alluvial lands increased, attracted by their richness, and we are confronted to-day with a situation of some 30,000 square miles of the richest soil in the United States, perhaps in the world, settled densely, threatened to be settled still more densely, and clamoring for protection against these tremendous agencies of nature. As one of the previous speakers has said, science has not yet gotten to the point of controlling rainfall to a sufficient extent to have it only when we want it and fill the river only bank full. Reservoirs have been discussed by Captain Sherrill. What he has said and that which I have read, simply confirmed the opinion I have always entertained that the reservoir system might possibly be applied to part of one or two tributaries, at an enormous cost and considerable danger. Eventually these reservoir systems would be crowded out by the demands of increased population, or by their own silting up. In the meanwhile, much money would have been spent and no good accomplished.

We turn then to the next popular outcry: "Outlets."

It seems very reasonable. This tremendous amount of water is pouring down upon us in the months of February, March and April. Make outlets—get it out to the sea—is the cry. This is where I have to repeat myself. The Mississippi River, gentlemen, is not a stream, if I may use the expression, "without a soul." It is not inorganic—it is nearly organic. Alluvial streams generally are organic. They are rivers of their own formation, flowing through a channel or trough in the river-swamp traced by themselves. They are the path which they have left for themselves to reach the sea. They have filled everything else, but they have left the said channel for their own use, and that channel, gentlemen, it seems to me, like plant life, is organic. If a river has great current velocity, the laws of hydraulics teach us that its transporting power (the power of a river in transporting material along its flow to the sea) varies as the sixth power of its velocity. Its power of erosion (and what I mean by erosion is the power of destroying cohesion of material) varies only as the second power of its velocity, but its transporting power varies as the sixth power of its velocity. Double the velocity and its carrying power becomes 64 times as great. This is the secret of its organism. If for any reason this current velocity is increased and

doubled, it has the power of transporting 64 times as much material as it had when its velocity was unit, and if you follow this law you will see that a very slight increment in velocity causes a very great increment in silt-carrying capacity. Therefore, the secret of control of alluvial streams, according to river hydraulics, is not to allow the current velocity to slacken. Keep the current velocity going, increase it if possible and every slight increase in current velocity will mean a tremendous increase (to the sixth power) of the sediment carrying power of that stream.

The alluvial stream is a gigantic hydraulic dredge, and human agency must apply and guide the tremendous energy which is stored up in this water in motion.

Now, how to do it? Get pumps to accelerate these 1,700,000 cubic feet per second? I think even my expert colleagues of the Sewerage and Water Board would find it very difficult to design such pumps. Therefore, to my mind, increase the current velocity by every means possible, and if that can be done, not only will the sediment brought down from the watersheds of the East, West and North be carried to the sea and deposited there to build new lands, but if that current velocity is increased sufficiently the stream will assert its right, its privilege of development. It will erode and enlarge its own bed, thereby increasing its section. It will scour out its bottom and become deeper where it is shallow and wide, and it will cave its sides and become wider where it is narrow and deep. In other words, it will increase its size so as to accommodate itself to the quantity of water it must carry.

Just as your arm or your leg will have its muscles developed, if you exercise it and train it intelligently, so if the Mississippi River is controlled and guided intelligently it will grow in section so that it will carry its floods to the sea, where we want them to go, without damage to us. Eventually this end will be accomplished by an increased section and current velocity, without any increase of flood height and therefore of danger.

Of course, during the process of development, of training, as it were, conditions are often strenuous. I have tried training. The process is pretty strenuous and awfully hard, but when the training has been accomplished and the muscles are hardened, then the work becomes easy. We are now trying to train this river to do its work.

The reservoir system I feel compelled, and reluctantly, to brush aside. The outlet theory I must also brush aside for two reasons. First, north of the Red River there is no possible outlet, and, second, south of Red River any outlet produces permanent harmful results.

North of Red River, on the west bank, the St. Francis Basin is not an outlet. It is a destructive reservoir. All water that enters it through crevasses fills it up, slackens the current velocity below the crevasse, causes bars, and then returns to the parent stream at Helena, enormously increasing the flood height at that point. This

has been proven. On the east bank, the Yazoo Basin, another enormous destructive reservoir, which was used this year, and caused the destruction of I know not how many millions of dollars of property, poured its water back in the river at Vicksburg and increased the flood height. The Tensas Basin, on the west, again may fill up as a reservoir, destroying itself—the very thing we don't want it to do—returning at Red River and adding to the flood height. We come, therefore, south of Red River, where, we are sorry to say, two reservoirs filled this year—the Atchafalaya Basin and the Lafourche Basin. The relief to the flood may have been perhaps 1 or 1½ feet, and the destruction to property enormous. However, I will say temporary relief, for there was a permanent deterioration of the stream bed below its outlets. This is a fact recognized by all hydraulic engineers, from those of the old school down to those familiar with the present highest development in the study of hydraulic science as expounded by the investigations of the Mississippi River. With an outlet, you have a checking of the current velocity below it, a deadening of the current. Having a slackening of the current velocity you ought to have a bar or constriction of the stream below it, and you have it every time. Repeated soundings have shown this. Let the outlet remain open two or say four years, and that stricture becomes permanent. The flood height (which may have been problematically relieved temporarily at the time of the occurrence of the crevasse) at the end of 3 or 4 years regains its own as the parent stream below it has had its section, its carrying capacity deteriorated by sedimentation, and the combined discharging capacity of the two outlets is only equal to the original capacity of the parent stream. Just as a slight increase in velocity increases tremendously the carrying capacity of the stream, so the converse is true. A slight decrease of the velocity stops tremendously the sediment carrying capacity of the stream and forms sedimentation below the outlet. This has been repeatedly confirmed, it is no longer a matter of hypothesis or theory. It is a fact.

If we had a clear water stream in a rocky bed, all right, we might have outlets, but we see that in a sedimentary stream outlets are pernicious. The very nature of the remedy proposed by the outlet deteriorates the stream. We have been compelled to abandon the reservoir idea as inefficient and over expensive. We are then left with only two alternatives, either go on and protect ourselves by increasing our levee system, or else go out of the country. I don't think the people are ready to move out of the country—they don't seem inclined to do that.

Now, as a matter of fact, bear in mind I have said that we are now during the period of training, that when we have gotten that stream big enough, deep enough, wide enough, it will carry its waters to the Gulf without reaching abnormal flood heights, but we have got to put up with it while training that stream. What has been the

experience of the past. In 1882 we had crevasses galore—the entire country overflowed. Levee construction came on in earnest about 1890, the districts raised large sums, the United States Government then began lending a helpful hand, much levee work was done between 1890 and 1910. In 1897 we had exceedingly high water, exceeding that of 1882 considerably. I could give you the exact records, but roughly it was considerably over 5 or 6 feet in many cases. The water in 1897 was held with very little disaster compared to the water in 1882, although flood heights were excessive. This showed what endeavor and the judicious expenditure of money had done. From 1897 to 1903 there were no very high waters. 1903 came with a record-breaking flood and fewer crevasses. It would seem that high waters occur in cycles of approximately 8 years, that during cycles of 8 years the first 2 or 3 years may experience high water, the remaining 4 or 5 years low. There does not seem to be any known reason for it, but that seems to be history in the last 50 years where records have been kept. Perhaps later on, when the science of meteorology is more advanced, we will understand the reason for this. Between 1890 and 1912 we have, with our levee system, been protected absolutely against all ordinary waters and practically against the extraordinary waters of 1897 and 1903. Quite a good deal to say for the levee system. Nobody ever saw that the levee system was completed. All of the engineers who are familiar with the subject simply said that they had spent money to the best of their ability and their knowledge. They had to make temporary barriers against the floods and succeeded in doing a great deal in protecting the country 9 years out of every 10, even 14 out of every 15; that was accomplishing a good deal.

Now, the water of 1912 came upon us, an extraordinarily high water, enormous rainfall. The exact records are not compiled yet, but an enormous rainfall and perhaps greater than that of 1882. The flood wave came down and broke about six important levees. Now, we had accomplished in this country a whole lot of development in a very few years. The impetus which was given to the development of lands in the valley in the last few years has been due to the sense of security which the people have had from their increased protection, and this has been due directly to the levee system. Because we had one year of disaster, which was unfortunately considerable, but by no means universal, and not nearly as great as some yellow newspaper reported (yellow newspapers have to sell by sensational news), the reliability of the levee system is questioned. We must keep on. Is it so difficult? What is the estimate of cost? 60,000,000 cubic yards for the State of Louisiana, for a 10 foot crown 3 feet above the high water of this year, with slopes of 3 and 4 to 1. The slope of the embankments I would double. I believe in big levees; make it 120,000,000 cubic yards for the State of Louisiana, and another 120,000,000 cubic yards for the balance of the Valley. 240,-

000,00 cubic yards, which will give us 20-foot crown levees, big section, heavy work, such as the Holland dikes. Such section as was not phased this year by high water and had margin to spare. 240,000,000 cubic yards of earthwork at 25 cents per yard, which is an average estimate, would be \$60,000,000. I think the Panama Canal has cost say \$276,000,000 to the present time, and will run up to \$400,000,000. Now, \$60,000,000 is not so very much for the United States Government and the local authorities to put up. If they can't put it up in one year—they could not build the system in one year, it would take 6 or 10 years to do it. In 6 years it would be \$10,000,000 a year. That is not much of a sum; then we would have levees which would protect the Valley 49 years out of every 50 years, perhaps for all time, but anyway let us assume 49 years out of every 50 years, that would be a pretty good expenditure. There are something like 19,000,000 acres in the alluvial valley of the Mississippi River, and it would not be idle to say that these would be worth \$100 an acre if they were so protected, which would make \$1,900,000,000 value for an expenditure of \$60,000,000, about 3 per cent. of the value of the property. Three per cent. expended throughout six years would mean one-half of one per cent. annually paid for six years for eventually permanent protection. We pay one-half of one per cent. for fire insurance, annually, on our property, without hope of eventual protection, and this is a continuous tax.

Therefore, gentlemen, to my mind, in the light of what we have done in the past with the limited means, with very little help from the National Government, the protection we have given to this Valley with levees, and levees alone, shows that they are a paying investment and that we should go ahead. The National Government now realizes that this is no longer a local problem. The people North, East and West, who deal with us, who sell to us, realize that if we are not buying their goods this year it is because nature has imposed upon us a drainage servitude, the drainage of 41 per cent. of the United States. There is that great ditch which nature has dug in front of our homes. They realize that the burden of this control should not be placed on our shoulders alone. The people of the United States are willing now, I firmly believe, to make liberal appropriations in recognition of that principle. We are willing to keep on taxing ourselves, as far as I can see. Of course, we would like to have the Government take full charge of the work so that we might not have to pay levee taxes at all. I would like it very much. However, that which is worth having is worth paying for, and I believe that nine-tenths of the right thinking people of the Valley are willing to go into their pockets and help protect themselves, saying to the National Government: "We can't do it all, you will have to come in and help protect us from that danger, from that suffering and destruction which the drainage of your country imposes upon us." Let us go at it upon that principle. Our cause is good, it can stand on

its own merits. We do not need to form alliances with projects of doubtful merit, in order to help it along; these might prove entanglements which would delay the recognition of our just demands. Let us stand on our own ground and demand of Congress that assistance which is due to us. Congress will be willing to listen to us. A powerful object lesson has been taught this year, and I think the humanity and good sense of the American people recognize that they owe it to themselves and to us to help in this protection.

FORESTATION AND ITS RELATION TO FLOOD WATERS OF THE LOWER MISSISSIPPI RIVER

Prof. W. B. Gregory, Tulane University.

The paper assigned to me is one on which a volume might well be written to present the many arguments that have been advanced for and against forestation as a means of flood control. But with full knowledge regarding the length of the programme that has been arranged for to-night, it was thought to be proper to limit this paper to concise statement of a few facts and arguments as presented by some of the highest authorities in this country. All that will be presented is already available in libraries and is doubtless well known to many and especially to engineers.

In the last four or five years a great mass of literature, in which this subject has been discussed, has appeared in the Engineering News, the Transactions of the American Society of Civil Engineers, in documents of the House of Representatives at Washington and in various bulletins of the United States Department of Agriculture and the Forestry Bureau.

One of the authorities on the question under consideration is Captain Chittenden of the United States Army. His paper in the Transaction of the American Society, Civil Engineers, Volume 62, March 1909, is entitled "Forests and Reservoirs in Their Relation to Stream Flow, with Particular Reference to Navigable Rivers."

He opens the subject by stating that it is the commonly accepted theory that forests have a beneficial effect on stream flow:

(1) "By storing the waters from rain and melting snow in the bed of humus that develops under forest cover, preventing their rapid rush to the streams and paying them out gradually afterward, acting as true reservoirs in equalizing the run-off."

(2) "By retarding the snow melting in the spring and prolonging the run-off from that source."

(3) "By increasing precipitation."

(4) "By preventing erosion of the soil on steep slopes and thereby protecting watercourses, canals, reservoirs and similar works from accumulation of silt."

When these statements are examined in detail and proofs are sought that will establish them as demonstrated facts the trouble begins. Captain Chittenden traces the origin of these popular beliefs largely to the writings of Sir Gustav Wax, Chief Engineer on the improvement of the Danube, about forty years ago, and states that

while they are still believed by a few engineers they appear to be accepted by the popular mind, practically without question.

To establish the truth or falsity of these propositions involves problems containing many variables. The definite proofs that are sought are so modified by the local conditions that data which seems at first to be convincing proves, on closer examination, to lead to an opposite conclusion. As Captain Chittenden says:

"The elements of the problem are so many and so conflicting, the evidence so hard to get, and comparative records are of such recent date, that precise demonstration is scarcely possible."

In discussing the effect of forests upon the run-off from rain-fall, Captain Chittenden affirms that the action of the forest bed to retain water may be accepted as strictly true for average conditions, but that is not true for extreme conditions—great floods and excessive low water—the conditions that determine the character and cost of river control. He points out the fact that great floods due to rain-fall, occur at times of unusual precipitations when the humus that covers the forest is thoroughly saturated with water. In such a condition it is unable to exert any restraining influence on the run-off.

The influence of forests on snow melting is discussed by Captain Chittenden at great length. It is claimed that snow is more evenly distributed in forests than in open country where it has a tendency to drift into deep banks. The snow melting begins in the open country earlier than in the forest. The water from the first melting of snow is absorbed by the snow below. In the forest where shade delays the melting, the greatest amount of melting is likely to be accompanied by a warm rain in which case the run-off will be that due to the combined rain-fall and the snow, and may cause a disastrous flood. On the other hand, the snow from open country will often melt away and disappear before that in the forest has melted and will not cause excessive run-off.

In the discussion of the paper the author is taken to task by Mr. Geo. Otis Smith, Director of the United States Geological Survey, Mr. M. O. Leighton, Chief Hydrographic, United States Geological Survey, and Mr. Gifford Pinchot, because he has overlooked the fact that a great deal of water will soak into the soil under the bed of humus that usually covers a forest, and, on numerous other points.

The statement of the delayed melting of snow in forests is challenged by Mr. Geo. Otis Smith and others, whose observations in the Northwest do not coincide with those of Captain Chittenden, while some of the men who join in the discussion heartily agree with the author.

Both the criticisms and the replies appear to be from men who are deeply in earnest—at times they are almost bitter.

The effect of forests on flood control is capable of experimental proof. However, there is very little information of a positive nature

that will aid in solving this problem. As a sample of available data, the following is quoted from a Press Bulletin of the United States Geological Survey, which appeared only last week:

"The report of the Geological Survey is based on the results of exhaustive investigations and specific field tests which have been carried on during the last year. While the Survey has been subjected to frequent criticisms and even bitter attacks, owing to its refusal to submit a perfunctory report assuming that a known and definite relation exists between forests and stream flow in the White Mountain region, the outcome of its investigations must not only satisfy the most radical forest enthusiast, but it precludes the possibility of criticism by those who have opposed the acquisition by the Government of any forest lands, on the theory that forest preservation does not affect stream flow. The investigations are believed, indeed, to solve definitely a problem that has long been a source of strenuous contention among scientists, including the friends of forest conservation, and while these investigations have direct reference to the entire White Mountain area, they establish a principle which is of far wider application.

"The hydrometric showing presenting in the preliminary report covers results on two small, almost exactly similar drainage basins of about five square miles each, on the East branch of Pemigewasset River, one largely clothed with virgin timber and the other deforested and burned. The facts observed are so striking as to render the position of the Survey impregnable. Careful measurements of precipitation over the areas and of the run-off of the respective streams show that not only was the snow held better in the forested area, but that during a period of seventeen days in April, including three extended storms, the run-off of the streams in the deforested area was a comparative flood—practically double that of the stream flowing through the forested area. The figures are as follows: Run-off of Shoal Pond Brook (forested area) during three storms in April, 1912, 6.48 inches; run-off of Burnt Brook (deforested area) during same storms, 12.87 inches.

"The results of the Burnt Brook and Shoal Pond Brook studies are held to show that throughout the White Mountains the removal of forest-growth must be expected to decrease the natural steadiness of dependent streams during the spring months at least."

It is supposed that all the factors have received careful consideration and that the conclusions stated would be found by any other competent scientist who may review the data.

There is much evidence on the other side of the question. The voluminous paper of Captain Chittenden, with its accompanying discussions, shows quite clearly that different men may take the same information and interpret it differently.

As an example of testimony on the opposite side of the question from that presented above, the discussion of Captain Chittenden's

paper by Messrs. Liffingwell & Strong is quoted. In the discussion of extensive data regarding floods on four rivers in California they make this statement: "From the data presented it is seen that the fluctuations of flow in these streams bears a striking relation, and apparently a direct proportion, to the amount of forest covers over the drainage areas."

These statements are given as examples of the conflicting information that is available. Massachusetts and California are far apart and it may be that local peculiarities in conditions of soils, forests and climate have not been fully considered.

In a recent bulletin by Dr. Willis L. Moore, Chief of the United States Weather Bureau, the following occurs:

"It has frequently been stated that forests control the flow of streams, both in high-water stages and in low-water stages, and that the climate is so materially affected by the cutting away of the forests that droughts have largely increased and that the well-being of future generations is seriously menaced. It is my purpose to present facts and figures that do not support these views, some of which, especially those that pertain to the flow of streams, were held by me up to a few years ago, until a careful study of our own and other records and of the incidents of history caused me to modify my opinions. I shall endeavor not to be dogmatic, but rather to present the reasons for the conclusions that I now entertain, with, so far as may be, statistical and historical evidence to sustain them. And I reserve the right to change or still further modify my views if the presentation of new facts and figures render such a course logical, and do not consider that I shall stultify myself in so doing."

A little further on he uses these words:

"There are so many reasons why forests should be protected by the State and the Nation and economically conserved in the interests of the whole people that it is doing an injury to a good cause to attempt to bring to its support the false reasoning and mistaken conclusions of enthusiasts, no matter how well meaning they may be or how devoted to high and lofty purposes.

"The general tendency, with growth of population, is to convert forest lands into cultivated fields, and this tendency should not be discouraged unless it can be shown that deforestation has augmented droughts and floods, and I believe that it cannot be shown; I believe that forests should be preserved for themselves alone, or not at all."

Dr. Moore gives some valuable data in regard to the relationship between forests and precipitation, after which he says:

"This indicates that instead of a diminishing rainfall we have the evidence that, if there is any variation at all in the precipitation, it is a slight increase for this region," referring to New England, where for many years the forests have been disappearing.

He sums the matter up as follows:

"On the whole, it is probable that forests have little to do with the height of floods in main tributaries and principal streams, since they occur only as the result of extensive and heavy rains, after the ground is everywhere saturated, or when heavy warm rains come on the top of deep snows."

The question of erosion is fully discussed in the several papers already referred to and the same difference of opinion already noted is found in the discussions, but time will not permit further reference to this subject.

It is a fact worthy of note that nearly all the engineers who have looked carefully into this matter, agree with Captain Chittenden and Dr. Moore that the forests have very little effect on floods in general and that the effect, if any, may be beneficial or harmful, as the evidence is about equally divided on that point.

At any rate, the flood waters of the lower Mississippi are the run-off from many different sections, widely separated, and conditions causing floods may be quite dissimilar, so that a remedy for one part of the watershed would not apply to another part.

From the available information it seems probable that any effect that forestation could have on our flood problem is practically negligible.

THE EFFECT OF MISSISSIPPI RIVER FLOODS ON LAND RECLAMATION AND DRAINAGE.

Arthur M. Shaw, Consulting Engineer.

It is assumed that in selecting the subject of this paper, the committee had in mind the moral effect which the floods may have on settlers or investors rather than the physical effect of occasional overflows on the engineering works of the various reclamation projects of this section. With this idea in mind, only a moment will be given to the latter phase of the subject.

In most reclamation plans, no cognizance is taken of possible overflow from the Mississippi River, and this is as it should be, for if we were to provide levees of sufficient height and strength to keep out all possible crevasse water, the funds for land reclamation would never become available. Land values have not yet reached the point that would justify this extravagant method of protection. Fortunately, such excessively high levees are not required. The occasional floods, disastrous as they are, do not even now come with sufficient frequency to cause the abandonment of any otherwise worthy reclamation project, and in spite of the discouraging and disheartening experiences which many of them have just passed through, we may expect to see the people returning to their lands, as the waters recede, to find their crops destroyed, it is true, and some minor damage done to their canals and levees, but they will find the actual total damage (beyond the loss of crops and time) to be slight. In some instances it will be found that even the crops are not a total loss, while many of the flooded tracts will become ready for cultivation sufficiently early to permit a Fall planting of early maturing vegetables. On account of the greater financial resources of the large planter he is seldom completely ruined as the result of a single crevasse, but the small farmer is better able to recuperate quickly by the flexibility of his farming methods, which enable him to get in a late crop after his fields have once been flooded.

We should now consider the moral effect which river floods have on those who may be investing their money in the development of the wet lands of the State and on those who will settle on these lands after they are reclaimed. This resolves our problem into one of psychology rather than engineering, but it loses none of its interest thereby. It will be conceded that in spite of the fact that this immediate community was one of the first to be settled in this country, the reclamation of the marsh lands of the lower valley is a comparatively new work, and those who subdue and till these lands are true

pioneers. Scores of examples of a similar people, settling in a new country and developing it under even more trying circumstances, show that our occasional river floods will not cause the abandonment of the present plans to reclaim the Louisiana prairies, nor will they even permanently hamper or interfere with such plans. Civilized man has a tenacity of purpose which has enabled him to subdue and make habitable the waste places. As a race, we are aggressive but not nomadic. Individuals may develop a tendency to roam from point to point, but as a people we have never been driven by adversity from a rich and fertile land. There has frequently been an exodus of large bands from one section to another, but these have been made up of the excess of population and such a movement has never resulted in the abandonment of a territory once held. This does not apply to nations and governments, but to the people who settle or make their homes in the land. History is full of examples of entire colonies who have lived through far greater privations and adversities than those experienced by the dwellers in the flood plains of the Mississippi Valley. The Cavaliers of Maryland and the Puritans of New England, the Dutch of New York and the Spanish colonists of the Southwest, all entered strange lands and faced death in a thousand forms, but the people have never abandoned their lands.

We have in this room descendants of the courageous French pioneers who braved the perils of the early colony and the persecutions of the Spanish governors to leave to their posterity some of the most beautiful homes of our country.

In our own times we have learned of the trying experiences of the settlers of the Middle West. When the Dakotas, Nebraska, and Kansas were first boomed, a few years of plenty for the early settlers were followed by an exceptional cycle of drought and low prices. This occurred just as the boom was at its height and resulted in almost unbelievable loss and suffering. The settlers knew nothing of modern "dry farming" and had not the financial resources to carry them through several years of poor crops. New methods of cultivation have been developed so that similar droughts are now passed through with little resulting loss. Thirty years ago the old-time prairie schooner was still a common sight, and, as a boy, I was particularly impressed by one which passed our home in Northern Illinois bearing this legend:

"In God we trust;
Kansas or bust."

Late in the Fall the same wagon passed on its return trip with the added line in fresh paint:

"We Busted."

Another discouraged rover returned eastward with the following bit painted on the canvas cover of his schooner:

“Nebraska and irrigation,
Kansas and starvation,
Hayes’ administration,
Hell and damnation,
Goin’ home to my wife’s relations.”

This local ebb flow was of short duration however, and all the agricultural states are now increasing in population and wealth.

We may expect that the flood of this year will affect the reclamation projects of Louisiana adversely, but this effect will not be permanent and prompt resumption of normal conditions is to be expected. The real tide of immigration to this section has scarcely begun and I confidently expect that the next few years will see great numbers of Northern farmers looking to Louisiana for the only cheap productive lands that are now easily available and favorably situated. It hardly need be said that this rather optimistic view of the question should not lessen our efforts to secure the proper regulation of the river. Our losses from this source are out of all proportion to the cost of adequate protection, and no time should be lost in doing whatever may be necessary to insure the lower valley from any possibility of periodical overflows.

We might now consider, not the effect of river floods on land reclamation and drainage but the effect of land reclamation and drainage on river floods. It is to be noted that a large proportion of the money invested in Louisiana reclamation work comes from various sections of the North, and right there is where we are going to develop a tremendous fighting strength in support of proposed Federal aid in the proper construction of our river levees. It is generally conceded that where a man’s money is, there is his heart (and his vote) also. It is this vital personal interest among men of large affairs in several sections of the country which will make it possible to enact laws providing the necessary means for proper levee construction. Please do not understand that any claim is made that it will be the Northern investors who will secure the necessary legislation. We must bear the brunt of the fight for additional appropriations and must make this fight an earnest and a hard one, but by properly placing the matter to those non-residents who have here a personal and a selfish interest, we will develop a source of assistance not heretofore available. It is apparent that those owning or living on the reclaimed lands of the valley have little personal interest in the exact method used to control the river, but it is hard to see how their interests can better be safeguarded than by the early construction and proper maintenance of a system of levees which will be of ample height and cross-section to hold in place the Father of Waters.

**FLOOD PROTECTION OF NEW ORLEANS.
TOPOGRAPHY AND GEOLOGY OF THE MISSISSIPPI
RIVER VALLEY.**

Sidney F. Lewis, Chief Engineer, Orleans Levee Board.

Geologists tell us that in Eastern North America, during the Paleozoic ages, the great Appalachian range of mountains lifted their heads high over the sea for centuries and centuries before the western border, the Rocky mountain range, appeared above the surface. In the cretaceous period of Mesozoic time, the Rocky Mountain region had become dry land, and its present height was gradually attained later in the Tertiary period, and became the western wall of the Mississippi Valley.

"To fill in the space between this wall and the older one on the east, nature taxed all her resources of land building agencies, and for ages upon ages the forest, the rain, the river, the glacier, decomposing, pulverizing, transporting and assorting the solid stuff of the mountain sides; plants and animals, living, growing, dying, rotting and mingling their dead tissues with the deader dust of rocks in a soil waiting only the seed of the sower to blossom into new forms of vitality for the use of the heir of the manor, man, when he should come into his princely inheritance, the Mississippi River Valley. For there is no sub-division of the earth's surface, which, if we take into account its area, the value and diversity of its productions, and the thrift, wealth, intelligence and progressiveness of its population that has its parallel on the globe."

The Mississippi River System.

The great river system of the Mississippi, with its trunk line, penetrates the heart of the most fertile section of the Valley for a distance of about 2,500 miles; and its 15,000 miles of navigable tributaries ramify in all directions towards its remote limits. It drains a territory whose area equals in extent the combined area of Austria, Germany, Holland, France, Italy, Portugal, Spain, Norway and Great Britain.

The river itself, in its winding course, covers a range of $6\frac{1}{4}$ degrees in longitude and $18\frac{1}{2}$ degrees in latitude. The headwaters of its tributaries extend in longitude from New York on the east to Western Montana on the west; and reach in latitude from British America on the north to the Gulf of Mexico on the south; or about 1,800 miles in longitude and 1,500 miles in latitude.

Drainage Area.

This vast drainage area, 1,256,000 square miles in extent, is equal to nearly one-half of the total area of the United States. It touches

thirty-two States, and two Provinces of the British Possessions. Only eight States to the eastward, and seven States to the westward, lie entirely beyond the confines of this great basin. This stupendous process of land making and extension has not only come down to an immediate and recent geological period, but is in process yet.

At Cairo, Ill., 1,061 miles from the Gulf of Mexico, by the windings of the river, is gathered together the surplus rainfall of nearly a million square miles, concentrated by the confluence of the Tennessee, Cumberland, Ohio, Mississippi and Missouri Rivers; the last two uniting something over two hundred miles above. Here heads the Lower or Greater Mississippi.

The last remnant of the Appalachian sea was a narrow prolongation of the Gulf of Mexico extending to this meeting ground of rivers, into the head of which they poured their floods in a group of falls or cataracts of sublime grandeur. In the lapse of ages the detritus brought down by them filled this long frith and transformed it into a sloping alluvial plain of seven hundred miles in length and varying from twenty to forty miles in width, having a descent to the Gulf of about three hundred feet, and embracing an area of 29,790 square miles subject to overflow in its natural state during great floods.

This area is greater than that of the combined area of the State of Massachusetts, 8,315 square miles; Rhode Island, 1,250 square miles; New Jersey, 7,815 square miles, and Maryland, 12,210 square miles, or a total of 29,550 square miles.

If this area, which surpasses in richness the Valley of the Nile, richer than any other portion of this continent, had a population as numerous as the population of Belgium, 550 souls to the square mile, it would contain fully 15,000,000 people. Its tributaries could then be diverted, its headwaters impounded; their power so harnessed as to further the many meritorious projects that are now being agitated and spoken of. What a mighty Empire it would then be, how vastly important and how well worthy of and entitled to Government encouragement and assistance.

In the year 1538, Hernandez De Soto, one of the conquerors of Peru, a Spanish nobleman of great wealth and influence, with a splendid retinue of Knight-errants, penetrated step by step through the wilds of Florida, Georgia, Alabama and Mississippi, until they reached the banks of the Mississippi River, in April, 1541. They and the pioneers of civilization who came after them found this alluvial valley covered by a luxuriant growth of vegetation, forest trees, and deep cane brakes, and periodically covered by the overflowing waters of the river. The description given then will answer for to-day.

"The lapse of over three centuries has not changed the character of the stream. It was then described as it now is, as more than a mile in width, flowing with a strong current, and by the strength of its waters forcing a channel of great depth. The water was described

as being always muddy, and trees and timber were continually floating down the stream."

The pouring rains and melting snow in the Springtime through thousands of rivulets, creeks and branches, gathered into mighty floods, and swept down the Mississippi and its tributaries; they generally overtopped the river bank in many places and flowed in a thin sheet of water over the adjacent land. The thick undergrowth on the banks of the stream, by checking the rapid flow of the escaping water heavily charged with silt or sediment during flood periods, would cause the earth and sand held in suspension and carried along by the current to settle, and thus continually build up the banks. But the stronger currents in the rivers themselves wore away and cut the banks into the lower ground in some places; so that the work of building up and tearing down was forever going on, as, indeed, it still is; and consequently the river banks throughout their length were never built up to high water mark by the unassisted processes of nature.

Thus it was that when the earliest settlers began to open plantations along the water courses of the alluvial valley, they soon found it desirable for comfort and convenience, if not absolutely necessary for rendering the country habitable, to keep the flood water from flowing across the river banks and over their clearings and plantations.

The most obvious and natural means for preventing such overflow was, of course, to make the banks a little higher with a ridge of earth. Such a ridge, or levee, a few inches, or at most a few feet in height, was usually sufficient to protect the immediate front against ordinary floods, and was not a work of great cost or labor. The lower lands back from the river might still be inundated, but this was of little consequence while there was plenty left on the front.

Evolution of the Levee System.

The Engineer De la Tour who laid out New Orleans, in 1717, found it necessary to provide for a levee something over a mile in length to be raised in front of the city to preserve it from overflow, which, however, appears not to have been completed until ten years later, when levees were being built by the riparian owners for a distance of eighteen or twenty miles above and below the city. It required another hundred years to extend the levees up to the mouth of Red River, some two hundred miles above New Orleans, though by that time, 1828, there existed some disconnected and unfinished levees on the west bank of the Mississippi as far up as the mouth of the Arkansas, and some progress had been made in levee building on the Upper Lafourche, then one of the outlets of the Mississippi River.

The richness of these alluvial lands had attracted quite a large population, and the levees were rapidly extended. Between 1861 and 1865, neglect and the ravages of the Civil War destroyed the greater

part of this work, but with the return of peace it was promptly taken up again, and has ever since been prosecuted with more or less vigor.

All of the earlier levees were so small and low as to be frequently overtopped and broken by the floods. Their proportions, compared with those of the levees of to-day, appear almost absurdly insignificant. As late as 1851 the levees between New Orleans and Red River Landing, from actual measurements made by the United States Delta Survey, were found to have an average height of only $4\frac{1}{2}$ feet, the largest not exceeding 8 feet in height nor 32 feet in width of base.

From these small beginnings the levees system of the Lower Mississippi has been evolved to its present condition, and its future evolution seems destined to continue until the Lower Mississippi from Cairo to the Head of the Passes will have its embankment so broad and high, and the waters of the Greater Mississippi will be carried safely to the sea.

It is impossible to state what has been the cost of levees since their incipency; in the State of Louisiana and that part of Arkansas affecting Louisiana, since 1865 up to date, some 225 million cubic yards of earth has been placed in the levees, at a cost of \$50,000,000, 75 per cent. of which was paid by the State and organized Levee Districts, and 25 per cent. by the United States Government.

It is estimated that it would cost, to complete the entire line from the head of the St. Francis Basin to the head of the Passes, at a grade sufficiently high and strong to afford complete protection against floods at the highest probable stages, the sum of \$32,000,000, and the protection of same against the encroachment of the river from the caving of its banks, some \$12,000,000 more.

Crevasses and inundations, resulting in extensive loss of property, are liable to occur during all floods so long as the system is incomplete. The increasing strength of the levees will be best understood by a comparison of the loss inflicted upon them by previous floods. In 1882 the total number of crevasses in the levees was 284, aggregating 56.09 miles in width, two-thirds of the entire valley was practically inundated. In 1883 the number of crevasses was 224, with an aggregate width of 34.1 miles. In 1884 the crevasses numbered 204, aggregating 10.64 miles in width. In 1890 the total number of crevasses was 23, aggregating $4\frac{1}{4}$ miles in width. In 1897 there were 38 crevasses, whose combined width was about 9.1 miles. In 1903, when the flood, in some places, reached stages as much as three feet higher than any previously known, there were six crevasses, aggregating $2\frac{1}{2}$ miles in width, or about one-sixth of one per cent. of the entire levee lines with a length of 1,470 miles, overflowing about 3,000 square miles out of 25,000, which showed an efficiency of 80 per cent. In 1908, with a flood as great as in 1903, there were few breaks in the levees, and with very much less territory overflowed, whilst the record of the recent flood has shown to have exceeded that of any previous high water as follows:

NAME OF GAUGE STATION	Elev. of Zero Gauge Cairo Dat.	Highest Water of record previous to 1912		High Water 1912	Difference Ft.	Estimated Ultimate High Water M. R. C.	Provisional Grade M. R. C.
Cairo	290.84	1883	52.20	54.00	+1.8	54.17	56.17
Memphis	203.97	1907	40.30	44.90	+4.6	41.60	43.60
Helena	161.98	1897	51.75	54.30	+2.55	54.10	56.10
Mouth White River	128.73	1903	53.70	56.30	+2.6	56.40	58.40
Arkansas City	116.44	1903	52.90	55.40	+2.5	56.30	58.30
Greenville	108.00	1903	49.10	50.50	+1.4	50.50	54.60
Lake Providence	89.62	1903	46.48	48.25	+1.77	48.00	51.00
Vicksburg	66.04	1897	52.48	51.90	-0.58	55.05	57.00
St. Joseph	52.74	1903	48.07	48.60	+0.53	50.80	52.80
Natchez	36.89	1903	50.35	51.40	+1.05	54.00	56.00
Red River Landing	23.85	1897	50.20	53.20	+3.00	52.50	54.50
Bayou Sara	23.95	1897	43.70	47.20	+3.50	45.70	47.70
Baton Rouge	20.06	1897	40.65	43.80	+3.15	43.20	45.20
Plaquemine	21.06	1897	36.25	39.74	+3.49	38.70	40.70
Donaldsonville	19.48	1897	32.75	34.80	+2.05	34.95	36.95
College Point	21.24	1897	27.95	30.18	+2.23	29.80	31.80
Carrollton	20.91	1893	19.42	20.70	+1.28	20.35	23.35
Fort Jackson	19.26	1897	8.30	8.50	+0.2	8.00	10.50

It did not reach at these points the provisional grade as established by the Mississippi River Commission. Of the area protected by levees in the State of Louisiana, some 20 per cent. has been overflowed by the existing crevasses, which is about 6 per cent. of the total area of the State.

The Mississippi River Commission was created by an Act of Congress, approved June 28th, 1879. The Act provides that it shall consist of seven members, of whom three were to be from the Engineer Corps of the Army, one from the Coast and Geodetic Survey, and three from civil life, of whom two were to be Civil Engineers by profession. Its duties are defined in part as follows:

"To take into consideration and mature such plan or plans and estimates as will correct, permanently locate and deepen the channel, and protect the banks of the Mississippi River; improve and give safety and ease to the navigation thereof; prevent destructive floods; promote and facilitate commerce, trade and the postal service."

Prior to 1882, the United States Government contributed nothing to levee protection. After the great flood of 1882, the Mississippi River Commission allotted money to levee building under the theory that in order to obtain and maintain deep low water navigation, a confinement of the waters within the banks by levees was necessary; and for many years following the amount spent by the Government on levees was limited to such stretches as were deemed by the River Commission as falling under the above consideration. No money, however, could be used for the express purpose of affording protection from overflow. Some twelve or thirteen years ago Congress removed this objectionable provision from the Rivers and Harbors Bill, and since then the Mississippi River Commission has made annual allotments to the several Levee Districts for levees, for the purpose of giving protection from overflow, and has expended some \$13,000,000 on the levees in the State of Louisiana.

Of the 1,496 miles of levees on the Mississippi River, some 778 miles are in the State of Louisiana, and 72 miles in Arkansas (Chicot and Desha Counties), which protect the State of Louisiana. A most recent statement, compiled in the office of the Board of State Engineers, makes the number of cubic yards of levee work in Louisiana, and that part of Arkansas affecting Louisiana, contracted under each administration, from 1865 to April 20th, 1912, to be in round numbers as follows:

By the State.

73,250,000	cubic yards
\$20,400,000	cost

By the District.

80,500,000	cubic yards
\$16,000,000	cost

By the United States Government.

70,000,000	cubic yards
\$13,000,000	cost

Making a total of 224,000,000 cubic yards, at a cost of \$49,000,000.

The alluvial valley subject to overflow, and protected by levees, has been subdivided into Levee Districts, organized under the various State laws, and managed and operated by Boards of Commissioners. In the State of Louisiana there are some seventeen Districts. The first to be organized in this State is:

1. The Fifth Louisiana Levee District, by Act No. 44 of 1886.

The Board of Levee Commissioners of the Orleans Levee District was created by Act 93 of the General Assembly of the State of Louisiana, approved July 7th, 1890. Under the provisions of this Act, the Parish of Orleans was "formed into a Public Levee District," and a Board of Levee Commissioners, composed of nine persons possessing all the requisites of a qualified elector in said parish, administer the affairs of the district, seven of whom are appointed by the Governor of the State from the several municipal districts of the city, and two (the Mayor and the Commissioner of Public Works of the City of New Orleans) being ex-officio members of the Board.

The said Board of Levee Commissioners is charged with the construction and repairs and invested with the control and maintenance of all levees in the said Orleans District, whether on river, lake, canal or elsewhere. The said Board of Levee Commissioners, as to location, construction and repairs of all levees on the river front of said District, shall first have the approval in writing of the State Board of Engineers.

Length of Levee Lines.

The public levee lines of the District lie on both sides of the Mississippi River, that on the left or east bank being 12.09 miles, and that on the right or west bank 13.63 miles in length. The District also maintains lines of "Rear Protection Levee" aggregating about 46.8 miles in length.

Grades of Levees.

Of the 12.09 miles of levee on the left or east bank, 5.32 miles, or 44 per cent., of the line is 4 to 5 feet above the high water, 1903; 3.85 miles, or 31.8 per cent., is 3 to 4 feet; 1.62 miles, or 13.4 per cent., is 2 to 3 feet; and 1.3 miles, or 10.8 per cent., is 1 to 2 feet.

Of the 13.63 miles on the right or west bank, 1.9 miles, or 14 per cent. of the line, is 4 to 5 feet above the high water of 1903; .96 miles, or 7 per cent., is 3 to 4 feet; 5.22 miles, or 38 per cent., 2 to 3 feet; 4.85 miles, or 36 per cent., is 1 to 2 feet; 0.7 miles, or 5 per cent., is 1 foot.

In consequence of the low grades and other defects of a more or less serious character, here and there, the Orleans Levee District, in

response to public demand, some five years ago, inaugurated a movement to improve and maintain as rapidly as possible its levee lines along the Mississippi River to the grades and sections as recommended at that time by the Board of State Engineers.

Formula of the Board of State Engineers.

In general terms, this formula proposed an embankment of earth to be built and maintained to a grade not less than five feet above the high water of 1903, with a crown not less than fifty feet wide, river side slope not steeper than three horizontal to one vertical; and land side slope not steeper than ten horizontal to one vertical; the flattening of slopes and widening of crown beyond these limits to be governed by the special requirements of what is known as the "Commercial Front," on the left or east bank of the river. On the right or west bank of the river the levees to be raised and enlarged to a grade five feet above the high water of 1903, with crown ten feet wide; river side slope not steeper than three horizontal to one vertical, and land side slope not steeper than four horizontal to one vertical.

Provision of Funds.

In order to carry out this project necessarily involved a large outlay of money for the payment of property appropriated. Since the inauguration of the movement, on June 4th, 1907, brought about through a conference of the commercial exchanges of the city, with the Hon. N. C. Blanchard, then Governor of the State, the Mayor, and others, to improve and maintain the line of levees along the Mississippi River, protecting the City of New Orleans from overflow, as rapidly as practicable, and to the extent of all available funds derived for this purpose. Up to date some \$4,523,078.79 have been expended, which amount is divided as follows:

First: By contract work undertaken in construction, and enlargement of certain stretches of the levee line on the Mississippi River, amounting to 1,668,718.5 cubic yards of earth, and 1,264,145 feet of creosoted revetment, at a cost of \$994,971.28, which includes also \$8,612.44 for the demolition of the H. T. Lawler Milling & Trading Co., Ltd., Concrete Flour Mill.

Second: Maintenance, repair and operating expenses, approximating \$361,478.09; interest on bonds, approximating \$543,300.00, and some \$2,623,329.42 have been paid out for the purchase of property, which includes some \$415,447.73 of outstanding certificates issued for appropriation of property, bearing five per cent. interest; so far averaging, as shown by the work undertaken since the incipency of the project, nearly three times as much as the cost of the levee work itself.

The District appealed to the General Assembly of the State of Louisiana in 1908, and succeeded in having its previous bonded indebtedness of \$500,000.00 increased to \$3,000,000.00; this amount is

outstanding. The other sources of revenue are derived from the District tax authorized and permitted by law, which is an annual ad valorem tax of one mill on the dollar on all property subject to taxation in the District, and the annual allotment by the State of \$10,000.00 from the General Engineer Fund. The assessed valuation of the District, on the tax rolls of 1910 and 1911, was \$231,045,937.00 and \$233,383,437.00, respectively.

Future Work.

Whilst the levees have been very much improved since the high water of 1908, considerable work yet remains to be done to bring the line up to grade and section as recommended by the Board of State Engineers, as shown in detailed attached statements, approximately at 2,296,200 cubic yards, divided as follows:

Orleans Parish, left bank	1,635,000
Orleans Parish, right bank	661,200

Whilst from these statements it would appear on the surface to be quite an undertaking, and involving a large expenditure of money to complete this project of enlargement of the system of levees on the east bank of the river, the handling of earthwork by the use of mechanical devices has reduced the cost of actual levee work over fifty per cent. to what it was in the incipency of the project in 1907. As we progress in our work we are getting ahead of the commercial front of the city, and property values to be appropriated in the future, which in the past has taken over three times the amount of money spent on actual construction work, will not in the future consume so heavily the revenues derived from this purpose. This, however, is based on a conjecture that the banks of the river will remain permanent.

Bank Protection.

The urgency of the character of work required to protect the banks from caving, and to fix the harbor lines in the Port of New Orleans, has long been admitted by the United States Government, and considerable work has been accomplished through appeals to the Government by her commercial bodies and others.

Since its incipency in 1878, the United States Government has expended some \$2,000,000.00 in revetment of the banks with sub-aqueous mattress work, of which sum some \$707,000.00 has been expended since 1907, the inauguration of the project of enlarged levees by the Orleans Levee District.

The Board of Levee Commissioners of the Orleans Levee District have repeatedly announced that if the National Government will undertake the task of bank protection, and fix the harbor lines, the District will construct and maintain all the levee lines required.

SHOULD THE FEDERAL GOVERNMENT NOW ASSIST IN THE CONTROL OF THE LEVEE SYSTEM?

Frank M. Kerr, Chief Engineer Board of Louisiana State Engineers.

With so many subjects upon so many inviting fields of thought before us to-night, opportunity to do no more than, with a hop-skip-and-a-jump, touch upon the high spots of each, seems to me, within the space of this one sitting, possible.

Hence, the following apology for a treatment of the subject allotted to me, namely: "Should the Federal Government Now Assist in the Control of the Levee System?"

There does not appear to me to be any room for argument in regard to this question.

Nor is it a new proposition, for the Federal Government has already for the past thirty years been, by degrees, materially assisting in the control of levees.

Therefore, it is not a question of NOW assisting, but a patent, self-evident fact that the Federal Government not only SHOULD, but MUST greatly improve upon the extent and scope of its assistance in the control of the levee system.

Up to the year 1882, memorable as a most disastrous flood year, the Federal Government took no active part in this class of public improvement—that is, in the construction and maintenance of a system of levees in the Mississippi Valley to protect from overflow. Its activities, more or less spasmodic, tentative, and, comparatively speaking, aroused at intervals of time more or less few and far between, were confined to river and harbor control.

After the trying experience of 1882, however, on the plea, well taken and finally and fully recognized and accepted, that the construction and maintenance of a system of levees would aid in fixing the course of the river, and thereby contribute to the improvement of navigation, the Federal Government took its first step towards aiding in the control of the levee system.

But for this aid from the Federal Government in 1882, it is a matter of grave doubt as to what would have been the fate of the levee system in Louisiana, if not in the Lower Mississippi Valley, and all that so depends upon it—life and property, and progress and prosperity, and the uplifting of a great valley and a great people.

The high water of 1882 left the levee system overtopped generally, breached in no less than three hundred places, the aggregate width of which was over sixty (60) miles, and the people of the State utterly disheartened and demoralized.

The Federal Government, however, here came to the rescue, in a comparatively small way, it is true, but sufficiently to give the people new courage, and they once more put their shoulders to the wheel, and have kept it rolling ever since.

What has followed? An increase in the length of the levee lines of the State from 1,025 miles in 1882 to 1,636.5 miles in 1912; an increase in the cubical contents of these lines of levee, with corresponding improvement in grade and section, from about 25,000,000 cubic yards in 1882 to over 160,000,000 cubic yards in 1912, representing in dollars and cents the sum of \$49,100,591.60, of which the State of Louisiana and the Levee Districts of the State paid \$36,344,136.33, and the Federal Government \$12,756,815.27.

What did this accomplish? It has, the greater number of years, conducted, at extreme stages, past our doors, without even causing comment, the greatest floods known to the history of any valley.

Has the investment proven profitable? In 1882 the assessed valuation of the State of Louisiana was but \$197,417,125.14. In 1911 it was \$546,820,340.00, three-fifths of which enhancement in values occurred in the alluvial lands subject to overflow, and dependent upon levees.

It occurs to me, and should, I think, to anyone at all familiar with the problem, that this advance in the efficiency of our lines of defense against overflow is, to say the least, notable, and it could never have been brought about except through the aid received from the Federal Government.

Now, as encouraging as this has been, it does NOT suffice.

Experience has, beyond all question, shown us that levees, the greater number of times, even in their yet incomplete state, do insure immunity from overflow to the valley, and we have already done so much towards preparing them to meet the task imposed upon them, that we should not now hesitate to still further improve them. To now dally with other propositions, tangible only in speech and print, appears to me the height of folly.

With money enough and system enough to fix our caving banks, build our levees somewhat higher and broader, and indulge in some refinements in the preparation of base, where known to be needed, and where burrowing animals are known to infest localities—all matters of familiarity to the experienced levee engineer—the solution of the problem is easily within our grasp.

We do not immediately possess the full resources ourselves, and, even if we did, it is generally recognized by the States at large that it is neither fair nor just that the whole burden of combatting an invasion, for the source and advancement of which we are in no way responsible, should be imposed upon us.

Aid must be had, and that aid, in the natural order of things, must come from the Federal Government.

But it should come to us upon a direct, segregated basis, comprehending immediate expenditures for the accomplishment of practical results necessary to the protection of the valley from overflow, within a reasonable lapse of time, not coupled up with propositions, coordinate to some extent, but not necessary to the accomplishment of that which we, first and foremost, need ourselves—levees. Any other course must, in my opinion, indefinitely defer, if it does not altogether defeat, our chances for aid.

It may be all very well for those interested in propositions far removed from our borders, to come amongst us and sing in dulcet tones that might, under most circumstances and conditions, tend to "Soothe the savage breast, soften rocks, and bend the knotted oak," about conservation, reservoirs, power, irrigation, drainage, river control, and all that may follow in the wake of each combined, to be, in the dim and distant future, harnessed together into one grand vehicle of munificence and power, to convert our Valley into an Elysium of safety, progress and prosperity, but the Federal Government is slow, very, very, slow to be lured along such lines, all in a bunch, as it were, and the effort must sooner or later prove abortive through the evidence of its own utter impracticability of accomplishment within any time profitable to the present generation.

The levee lines in Louisiana, as a general proposition, remain, after this high water, in a better condition than after any extreme high water of the past. They present to-day a far better foundation for improvement than ever before after any extreme high water of the past, and can, if operations be promptly and vigorously inaugurated and carried out, be, in less time than ever before, brought to a standard equal to the highest water of record, just as has been the policy of the past.

To effect this, Federal aid cannot too soon be secured and accorded.

Federal aid and Federal control, however, are two very different propositions. But this is not down upon the program for me to-night, and had best be reserved for another chapter, at some other time.

INCREASED WEALTH TO BE DERIVED FROM EFFICIENT CONTROL OF FLOOD WATERS OF THE MISSISSIPPI RIVER.

George H. Davis, of Ford, Bacon & Davis, Engineers.

The subject of Mississippi River flood protection, with recommendations relating to levees, revetments, channel improvement, forestation and reservoirs, have been most ably presented in the addresses of the evening.

I can suggest only in general outline the economics of this vast undertaking. The continental portion of the United States, for the purposes of this discussion, may be separated into three divisions:

- (1) The section east of the Appalachian Mountain System, or Atlantic States;
- (2) The section west of the Rocky Mountain System, or Pacific States;
- (3) The section between the Appalachian and Rocky Mountain Systems, or the Mississippi Valley States.

The Mississippi Valley States contain approximately 40,000,000 of the population and \$50,000,000,000 of the wealth of the nation. There has been no equal area of land in the history of civilization which has contained so much natural and developed wealth as the Mississippi Valley. The protection of this is far more important in every particular than the joining of the commerce of the Atlantic and Pacific Oceans through the Panama Canal, in which the United States has, in ship-ownership at least, but a comparatively insignificant interest. There never has been any proposed public work in the world's history that has exceeded in importance the development of the levee revetment and channel system from the mouth of the Mississippi River north, thus protecting the vast riparian lands of the States of Louisiana, Mississippi, Missouri, Arkansas, Tennessee, Kentucky and others adjoining the Mississippi River system. This system of rivers drains about 40 per cent. of the area of the United States, and its potential, tangible and intangible wealth probably exceeds the present combined wealth of all the civilized nations, amounting to about \$500,000,000,000.

If the United States can spend \$400,000,000 in the construction of the Panama Canal, on account of world commerce, it can well afford to spend an equal amount for the protection of the invested wealth of the Mississippi Valley, owned principally by citizens of the United States.

The area subject to overflow is equivalent to 29,790 square miles, distributed by States as follows:

Louisiana	14,695 square miles		
Mississippi	6,926	"	"
Arkansas	4,652	"	"
Missouri	2,874	"	"
Tennessee	453	"	"
Kentucky	125	"	"
Illinois	65	"	"

The complete financial interdependence of modern nations and sections through communication and trade causes a disaster to become both nation-wide and world-wide in its consequences.

Without complete physical protection or ample insurance, the flood burdens fall heaviest upon the immediate sufferers. In the period of 1785 to 1912 (127 years) 30 floods in cycles of from 5 to 8 years have occurred in the Mississippi Valley. The records of the earlier floods contain no analyses of their business effects and the record of later floods furnish only approximate estimates. The various volumes of the Congressional Record since 1882, together with the official reports of the War Department and of Citizens' Commissions, furnish the most reliable information. A single agricultural parish of Louisiana in one year frequently loses in excess of \$1,000,000. Mr. A. G. Durns states in the "Standard History of New Orleans," referring to the flood of 1882, that "According to the reports prepared by the police juries at the request of the Governor, for the purpose of estimating the loss entailed upon Louisiana by the flood, it was shown that 28 out of 56 parishes were involved in it, the damage to crops of all kinds amounting to \$11,408,000; that to stock, fences, houses and goods, levees and railroads, to \$3,596,000, making a total of \$15,004,000 lost in Louisiana alone. In Mississippi the loss was figured at \$6,701,000; in Arkansas, at \$4,033,000; in Tennessee and other States, at \$1,300,000; the amount for all being \$27,038,000." It is conservative to assume that each of these floods entailed local losses, as variously estimated, depending upon the property contained in the flooded areas at from \$5,000,000 to \$30,000,000, a probable total in the past century of more than \$500,000,000. Could any section, except one of extreme natural wealth, remain supreme over such losses?

The intangible and indirect losses are in a sense incalculable. The whole wealth fabric of the world is built upon confidence. Confidence in nations, sections, structures, businesses and men.

The events which have particularly shaken the confidence of American and European investors and retarded the development of the great potential wealth of this section are the aftermaths of the Civil War, yellow fever epidemics and Mississippi River floods. The

effects of the War have been discounted and are now and forever behind us. Under present government control, yellow fever will never again appear. The confidence of the world regarding health and climatic conditions has been completely and permanently established. There now remains but one great project in the accomplishment of which we will merit the implicit confidence of the entire business world. Our particular need is not the disjointed action of individual States, but concerted action by the Federal Government, resulting in the complete maintenance of levees, revetments and channels, and their reconstruction where necessary. We are not asking sectional favors for the South in pleading for Federal control of flood protection. The floods do not originate within our own borders, but come from three corners of the continent, merely passing our doors. There are thirty-one States in the Mississippi drainage area, seven of which have land subject to overflow. As previously noted, Louisiana, Mississippi, Arkansas and Missouri sustain the direct tangible flood losses. In addition there are many cities of other States on the River or its tributaries that bear heavy flood burdens. It is axiomatic that the lower valley is worth saving, if not for us, then for its contribution to the financial strength of the nation. It is obvious that if about 40 per cent. of the national drainage causes the destruction of only 1 per cent. of its domains, it is a national affair. If war were in progress for the defense of this territory, would the forty-eight States of the Union sit idly by and allow Louisiana, Arkansas, Missouri and Mississippi to fight their national battles? Why does the nation spend vast sums in the development of the arid sections of the West, where there is no developed wealth and far less potential value, and allow the State of Louisiana alone to pay more annually for flood protection from foreign water than the National Government?

What are the specific losses resulting from uncertainty as to environment of investment?

A doubtful section of country loses by migration its most progressive inhabitants to sections of greater certainty. The average income per family in the United States, considering both wealth and wages, is approximately \$1,800 per annum. This is 6 per cent. annually on \$30,000. Why have we not received a greater share in the migration from other sections and immigration from abroad? If from uncertainty we have lost or failed to acquire 200,000 families, or 1,000,000 inhabitants, the equivalent in money would be \$6,000,000,000.

The recent passenger statistics of the trunk lines radiating from the Gulf States indicate that the South is acquiring by migration from the Middle West and other sections of the United States, as well as immigration from Southern Europe, between 350,000 and 450,000 residents per annum. This movement is the direct result of widespread confidence in our conditions. Confidence in the conservatism

of our laws, confidence in the healthfulness of our climate, confidence in the fertility of our soil, confidence in our people, and, finally, confidence in our freedom from disaster.

From 1900 to 1911 the South increased its wealth \$9,580,800,000, or 53.3 per cent. Do we want to see the tide turned?

From the high water period of 1903, when there were nine crevasses, to 1911, only one crevasse occurred. Never in the history of this section has business faith been so rapidly established.

For nearly eight years a feeling of enthusiasm for Southern investments has not only pervaded our own country, but European money centers as well. The surplus capital of Europe, as well as our own, has been pouring into the South, and especially the southern half of the Mississippi Valley.

The flood losses of 1912 have not as yet been computed. Whatever they are, they will be turned to profit. Not in a single fold, but a hundred fold.

The estimated total tangible wealth of Louisiana in 1911 was \$1,400,000,000; of Mississippi, \$990,000,000; of Arkansas, \$950,000,000, and of Missouri, \$4,500,000,000, a total of \$7,840,000,000. Considering an average business, its intangible value, including its value as a going concern, with all that the term implies, should be equal to its physical value. The wealth of States consists of business in the collective, consequently it would be fair to assume a present value tangible and intangible of these States, of \$15,680,000,000, equivalent to \$114 per acre of land area. On the same basis the present tangible and intangible value of the whole continental United States is approximately \$280,000,000,000, equivalent to \$147 per acre of land area, a difference of \$33 per acre.

When a condition of confidence is established at least 15,000,000 acres of land will be increased in value by nearly \$500,000,000, while the total increased values due to migrations of both people and money to the States affected, based upon the values established in the country at large, will amount to at least \$4,500,000,000.

Increased values beyond these will be in direct proportion to the greater productivity of this section, as compared with the general average.

Without a handicap in its race for supremacy, what is the business future of the South?

The present flood is not a great one as compared with those of the past, yet it has occurred at a moment when the friendly co-operation of the entire nation, through its investments in the South, is ours.

The first five of the largest industrial corporations of the United States have in five years greatly extended their interests in steel, oil and land developments in the South. The railroads and other transportation companies have also extended their lines and services. The expansion of these businesses, with its resulting stock and bond

distribution, has brought to our support a great body of investors, residing not only in the United States, but everywhere.

With the pressure of earnest public sentiment insisting upon the safety of investment, the Government will, based upon all precedent, assume the responsibility of Mississippi River flood control.

Regarding other public expenditures of the various cities, States and the nation in public works, which are now proposed or in progress, we may mention:

1. The Panama Canal	\$400,000,000
2. The reclamation of arid lands of the West.....	100,000,000
3. The New York State Barge Canal	100,000,000
4. The New York City new water supply	175,000,000

There are hundreds of smaller undertakings in bridges, river and harbor work structures and tunnels which are being completed at public expense. Ample business returns on these great obligations should be assured, either directly or indirectly, to the Government to warrant their assumption.

It is doubtful in the minds of some of the best economists whether the Panama Canal will return to the nation as a whole, or its citizens individually in the development of their various businesses, 4 per cent. annually. It may, however, to the general family of nations be a source of great profit, furnishing a corresponding increase in the world's composite wealth.

In the reclamation of arid lands there is again a question of ample return. The Government has now spent over \$60,000,000 and has reclaimed 1,000,000 acres. Arizona had a population in 1910 of only 204,354 and an estimated total developed wealth of approximately \$150,000,000, yet the Government has spent in the Salt River project, including the Roosevelt dam and the Gunnison tunnel, in excess of \$8,000,000. If a similar per capita expenditure were made for river protection in the riparian States of the Mississippi Valley subject to overflow, the total would be in excess of \$500,000,000.

The limit of arid land irrigation in the United States is from 60,000,000 to 100,000,000 acres contained in sixteen Western and Pacific Coast States. Drawing on every known feasible water supply, probably not to exceed half of this can be actually reclaimed, and its potential value would not exceed \$3,000,000,000.

The New York State barge canal probably furnishes less return to the public or the State Government than any undertaking now in progress. Regarding the water supply for New York City is an article by Walter McCullogh, which may be quoted:

"The Water Supply Commission was created in 1905, the primary object of its creation being to insure an equitable apportionment of the sources for water supply among the various municipalities and other civil districts of the State. * * * The most important of

these is the effort of the State of New York to acquire a new supply of water from the Catskill Mountains, amounting to 500,000,000 gallons per day, to be delivered through a tunnel aqueduct ninety miles long. The cost of the project is estimated at \$175,000,000, or more."

This brief review of the present basis of appropriation in profit or return on public expenditure cannot fail to suggest the extraordinary comparative financial merit of the project we are urging. The voice of the 12,000,000 people affected in the first degree, the 28,000,000 affected in the second degree, and the 52,000,000 affected in the third degree will be heard and heeded by Washington.

When this work is accomplished, the last possible barrier to Southern progress will be eliminated and the supremacy of this section will be finally and permanently established.